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Home Range and Habitat Selection in the Eastern Box Turtle (*Terrapene carolina carolina*) in a Longleaf Pine (*Pinus palustris*) Reserve

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***Abstract.*—The Eastern Box Turtle (*Terrapene carolina*) is a species of conservation concern throughout North America, with recent population declines attributed primarily to habitat loss. The habitat requirements of this species in the southeastern United States have not been fully described. Our objectives were to estimate home range size and to describe habitat selection of Eastern Box Turtles (subspecies *T. c. carolin*a) in a landscape dominated by Longleaf Pine (*Pinus palustris*) forest, the once dominant ecosystem in the Southeastern Coastal Plain. We conducted a radio-telemetry study of adult Eastern Box Turtles in a managed Longleaf Pine reserve in southwestern Georgia, USA. Home ranges expressed as 95% minimum convex polygons were 0.33–54.37 ha in size and averaged 10.33 ± 3.33 ha (SE). Turtles exhibited landscape-scale selection of pine-hardwood forests and hardwood forests. At a local scale, turtles used forbs more than bare ground, litter, and grass. Our study provides much-needed baseline information about home range size and habitat use of Eastern Box Turtles in the endangered Longleaf Pine ecosystem. Additional studies, particularly regarding use of disturbed habitats that are more characteristic of the modern southeastern landscape, would further clarify the status of Eastern Box Turtles in this region.**

Key Words.—Georgia; kernel density estimate; minimum convex polygon; radio-telemetry

Introduction

Eastern Box Turtles (*Terrapene carolina*) occur in the eastern and midwestern US, southern Ontario, Canada, and northern Mexico (Carr 1952; Dodd 2001). As a result of gradual, but at times pronounced, population declines over recent decades (e.g., Stickel 1978; Williams and Parker 1987; Hall et al. 1999), the species is listed in CITES Appendix II as vulnerable in the District of Columbia, Massachusetts, New York, and Pennsylvania, and as critically imperiled in Maine and New Hampshire (NatureServe. 2013. NatureServe Explorer: an online encyclopedia of life. Available from http://www.natureserve.org/explorer [Accessed 1 July 2014]). Most declines are linked to land use changes by humans, such as expanding road networks leading to vehicle strikes, habitat degradation and loss, and inflated populations of human-associated predators (Williams and Parker 1987; Hall et al. 1999), but commercial collection (Gibbons et al. 2000) and infectious diseases (Feldman et al. 2006; Johnson et al. 2008) are also contributing factors. Decreased adult survival, a hallmark of most documented declines in Eastern Box Turtles, is especially significant from a conservation perspective (Hall et al. 1999). The delayed maturity and slow rate of population growth that are typical of this species lead to slow recovery from losses (Hall et al. 1999). The conservation status of the Eastern Box Turtle warrants a more comprehensive understanding of its natural history and behavior, key components of which are area requirements and habitat selection (Stickel 1950; Conner and Godbois 2003). With the exception of extensive data for an isolated population on Egmont Key in Tampa Bay, Florida (Dodd et al. 1994; Dodd 2001; Jennings 2003), these attributes are largely unspecified for populations south of Maryland (Stickel 1950, 1989; Dodd 2001).

The home range of an animal refers to the area routinely used for daily activities including resting, foraging, thermoregulation, mating, and nesting (Burt 1943; Stickel 1950, 1989; Dodd 2001). Within a home range, most individuals use certain core areas more than others, presumably because resources are not evenly distributed across the landscape (Worton 1989; Chamberlain et al. 2003). Research throughout the range of the Eastern Box Turtle suggests that home ranges are typically from 1–5 ha in size (Dodd 2001) but can reach about 20–25 ha (Schwartz et al. 1984; Ernst and Lovich 2009). Variation in home range estimates may be due to geographic location and habitat quality (Kaufmann 1995; Nieuwolt 1996; Arvisais et al. 2002; Chamberlain et al. 2003). Thus, it is important to estimate home range across a variety of habitat types and geographic regions, especially in areas where previous work has been limited.

In the eastern portion of its range, the Eastern Box Turtle is generally associated with mesic forests, which meet the thermal and hydric requirements of the species (Reagan 1974; Dodd 2001). Longleaf Pine (*Pinus palustris*) forest was once the dominant forest type in the Southeastern Coastal Plain but has been reduced to < 3% of its historic range (Frost 1993). In light of this dramatic loss, it is important to determine the degree to which Eastern Box Turtles are associated with Longleaf Pine forests versus other available habitats in the southeastern United States. This is especially necessary considering that prescribed fire is an essential tool in restoration and management of remaining Longleaf Pine stands, but whether fire provides favorable habitat characteristics for Eastern Box Turtles in the southeastern region is not well documented. The objectives of this study were to describe home range size of Eastern Box Turtles (subspecies *T. c. carolina*) and to examine habitat selection at multiple spatial scales in a Longleaf Pine reserve managed with prescribed fire.

Materials and Methods

Study site.—We conducted our study at Ichauway, a privately owned reserve and the site of the Joseph W. Jones Ecological Research Center in Baker County, Georgia, USA (Fig. 1). Ichauway is dominated by second growth Longleaf Pine forest and has been intensively managed with prescribed fire since the early 1900s. The 11,769-ha property also contains other pines (e.g., Slash Pine, *Pinus elliottii*, Loblolly Pine, *P. taeda*, and Short-leaf Pine, *P. echinata*), hardwoods (typically oaks, *Quercus* spp.), wildlife food plots for the Northern Bobwhite (*Colinus virginianus*) and other game species (Boring 2001), and numerous semi-permanent to extremely ephemeral wetlands (Drew et al. 1998; Kirkman et al. 1998; Fig. 1). Two large streams, Flint River and Ichawaynochaway Creek, and several paved highways intersect the property. Center-pivot agriculture is the primary land use surrounding the reserve.

Radio-telemetry.—We collected Eastern Box Turtles opportunistically throughout Ichauway between August 2003 and March 2004. For each turtle, we measured body mass and straight-line carapace length (CL) and determined sex based on the degree of plastron concavity and eye color (Nichols 1939). We individually marked turtles by notching the marginal scutes with a triangular file (Cagle 1939). We outfitted 23 adult turtles (> 100 mm CL) with SM-1H radio transmitters weighing 26 g (AVM Instrument Co. Ltd., Livermore, California, USA). Transmitters were affixed to the costal scutes of the carapace with epoxy putty (Oatey Supply Chain Services, Cleveland, Ohio, USA). The weight of the radio

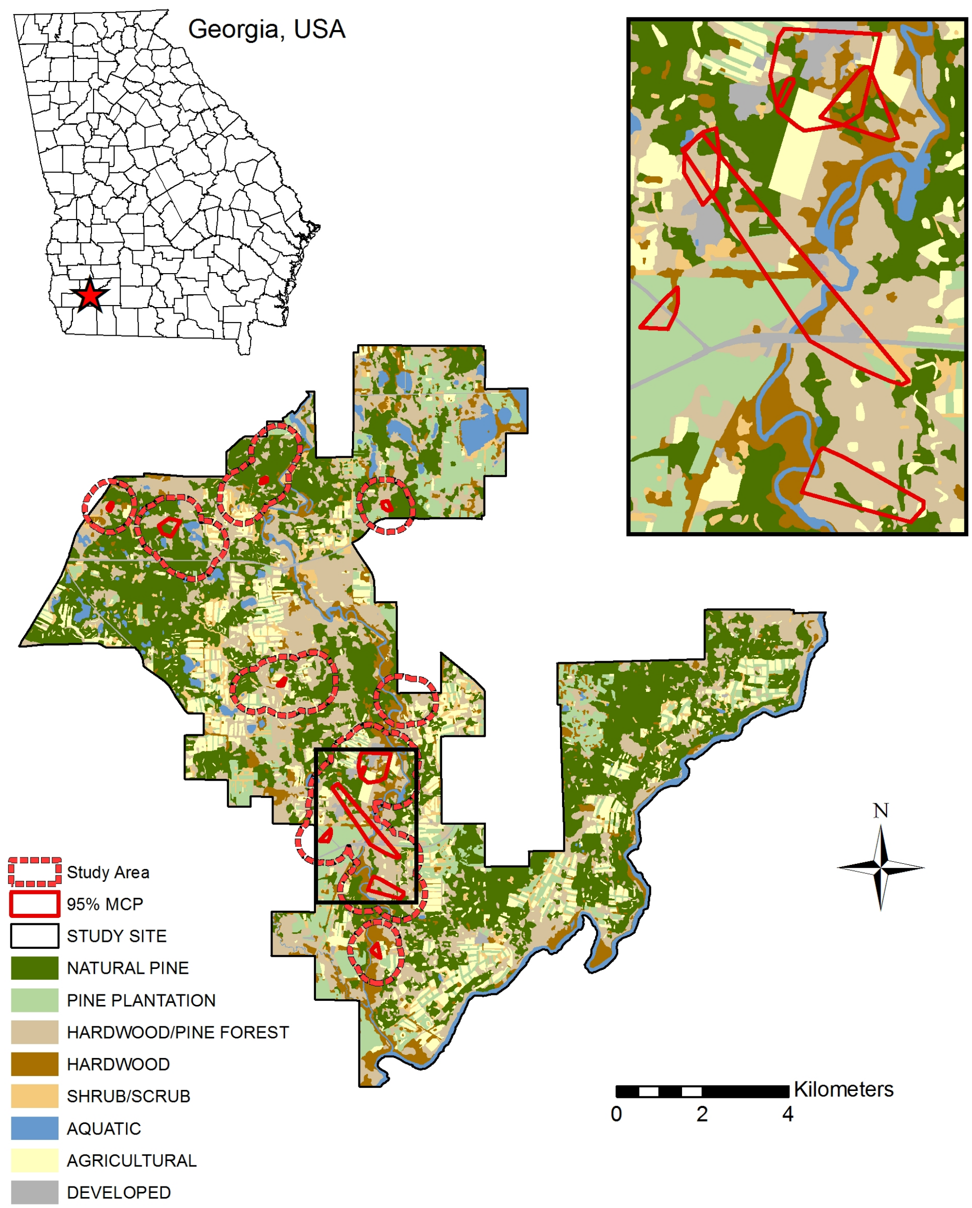

Figure 1. Study area for home range and habitat selection study of *Terrapene carolina carolina* at Ichauway reserve, Baker County, Georgia, USA.

transmitter and fixative averaged < 40 g (approximately 10% of the body mass of the turtle).

We released radio-tagged turtles at the point of capture and located each turtle at least once per week during the active season (March-November) and once every two weeks during the inactive season (December-March) between September 2003 and October 2004. We tracked turtles using an R1000 radio-telemetry receiver (Communications Specialists Inc., Orange, California, USA) and a folding Yagi 6-element antenna (Wildlife Materials Inc., Murphysboro, Illinois, USA). We radio-tracked turtles until signals were lost or the study ended (October 2004). We recorded turtle locations using either a Trimble GeoExplorer 3 (accurate to within 10 m) or a TrimbleARC1 (accurate to within 1 m; Trimble Navigation Systems Ltd., Sunnyvale, California, USA). We removed transmitters at the completion of the study.

Data analysis.—We performed statistical analyses with SAS 9.3 software (SAS Institute Inc., Cary, North Carolina, USA). We set a significance level of $\alpha = 0.05$. We performed spatial analyses with ArcMap 9.3.1 software (ESRI, Redlands, California, USA). We used an existing geographic information system delineating habitat types for Ichauway, produced by screen digitizing and ground-truthing 2006 color infrared digital aerial photography at 1-ft pixel resolution. Habitat types were pine forest, hardwood forest, pine-hardwood forest, agricultural, pine plantation, aquatic, shrub/scrub, and developed. Pine forest referred to mixed-age stands with > 90% Longleaf Pine (dominant across 90% of this habitat type), Slash Pine, Loblolly Pine, or Shortleaf Pine. Hardwood forest contained > 90% hardwoods including Red Oak (*Q. falcata*), Live Oak (*Q. virginiana*), Laurel Oak (*Q. laurifolia*), or Water Oak (*Q. nigra*). Pine-hardwood forest was composed of 20–80% pines or hardwoods. Agricultural land comprised wildlife food plots and other small croplands. Pine plantation consisted of newly planted to mature even-aged stands of Longleaf Pine or Slash Pine. Aquatic areas were forested and non-forested isolated wetlands, the Ichawaynochaway Creek, and the Flint River. Shrub/scrub included abandoned clearcuts and agricultural fields, failed pine plantations, and hardwood scrub. Developed areas were roads, houses and sheds.

For each turtle, we calculated two estimates of home range size, 95% minimum convex polygon (MCP; Mohr 1947) and 95% kernel density estimate (KDE; Worton 1989), and one estimate of core area size (50% KDE) using the Home Range Tools extension (HRT; Rodgers et al. 2007) in ArcMap. We selected smoothing factors (h) that generated 95% KDEs similar in area to the 95% MCPs (Row and Blouin-Demers 2006). We used linear regression (PROC REG) to determine whether home range size estimates were related to length of the tracking period (days) or number of locations.

We defined the study area as a 2,046-ha area encompassed by 500-m circular buffers around each MCP. When buffers of individual turtles overlapped, we used the Dissolve Tool to create a single, continuous polygon (Johnson l980; Fig. 1). A small portion of the study area fell outside of Ichauway in an area for which we had no habitat data. However, none of the turtles moved outside of Ichauway, indicating that the composition of the study area with habitat data was representative of habitat available to the turtles.

We used compositional analysis, a test of proportional habitat use relative to availability, to assess habitat selection by turtles, both with and without sex-specific comparisons (Aebischer et al. 1993). To assess habitat selection at the local scale, we compared habitat composition at unique turtle locations (i.e., telemetry locations in which the turtle had moved > 5 m from its preceding location) to habitat composition of the home ranges (95% KDE and 95% MCP), and habitat composition of the core areas (50% KDE) to that of the home ranges (95% KDE). To assess habitat selection at the landscape scale, we compared both habitat composition of the home ranges (95% KDE and 95% MCP) and of the core areas (50% KDE) to that of the study area (Johnson 1980). We performed multivariate analyses of variance (MANOVA) of log-ratio transformed data (PROC GLM). When a MANOVA indicated selection, we identified the habitat types selected by turtles with a ranking matrix of t-tests (PROC MEANS).

We assessed groundcover preferences with use-availability analyses (Neu et al. 1974). Here, we define use as the groundcover type at unique turtle locations, i.e., whenever a turtle moved > 5 m from its preceding location, we recorded the groundcover type on which it was presently sitting. Groundcover types were bare ground (no vegetation), litter (leaves and pine needles), grasses (predominantly Wiregrass, *Aristida stricta*, and Broomsedge, *Andropogon* spp.) and forbs (predominantly oak seedlings, *Quercus* spp., Silkgrass, *Pityopsis graminifolia*, blackberry, *Rubus* spp., and Poison Oak, *Toxicodendron radicans*). For analyses, data were summarized as percentage of all unique locations within each of the different groundcover types. We estimated groundcover availability with an existing data set for Ichauway that included percentages of groundcover types within 442 randomly placed 1-m^2 quadrats (Miller 2008). We used chi-square statistics (PROC FREQ) to test the hypothesis that groundcover types were used in proportion to their availability. If the null hypothesis was rejected ($\alpha < 0.05$), we employed confidence intervals following methods in Neu et al. (1974) to determine which groundcover types were used in proportions greater or less than availability.

Results

We radio-tracked 19 turtles (seven female, nine male, three of undetermined sex) for at least 4 mo of the active season. We excluded four individuals that were lost within 4 mo of tracking from analyses. We tracked individuals from 35–90 times over 174–401 d ($\bar{x}$ = 326 d; Appendix 1). MCPs were 0.33–54.37 ha and averaged 10.33 ± 3.33 ha. The average MCP for males (11.70 ± 5.75 ha) was larger than that for females (8.33 ± 5.68 ha). KDE home ranges were similar in area to MCPs, as we designed. Core areas were 0.09–10.44 ha and averaged 2.08 ± 0.62 ha. The average core area for males (2.33 ± 1.10 ha) was also larger than that for females (1.60 ± 0.99 ha; Appendix 1). Home range size estimates were not significantly related to length of time tracked ($r^2 = 0.021$, $P = 0.554$) or number of tracking events ($r^2 = 0.139$, $P = 0.116$). The relatively high degree of variation in MCPs was due to two individual turtles with exceptionally large home ranges (male 1135, MCP = 54.37 ha and female 1142, MCP 42.03 ha, Appendix 1). For comparison, the average MCP excluding these two individuals was 5.87 ± 1.36 ha.

Habitat use did not differ between female and male turtles ($F_{7,12} = 0.270$, $P = 0.950$), so we report results of models without a sex component. At the landscape scale, habitat composition of the study area differed from that of core areas ($F_{7,12} = 9.94$, $P < 0.001$) and home ranges (KDE: $F_{7,12} = 6.99$, $P = 0.002$; MCP: $F_{7,12} = 10.48$, $P < 0.001$). Specifically, the proportion of mixed pine-hardwood and hardwood forest in home ranges and core areas was greater than expected based on availability, whereas the proportions of agricultural land, aquatic habitats, developed areas, pine forests, pine plantations, and scrub-shrub habitat in home ranges were less than expected (Fig. 2). At the local scale, habitat composition of home ranges did not differ from that of core areas (KDE: $F_{7,12} = 0.96$, $P = 0.498$) or turtle locations (MCP: $F_{7,12} = 1.08$, $P = 0.431$; KDE: $F_{7,12} = 2.10$, $P = 0.123$). Eastern box turtle use of groundcover differed from random ($\chi^2 = 32.9$, df = 3, $P < 0.001$); turtles preferred groundcover comprised of forbs and avoided bare ground and litter (Fig. 3).

Discussion

To our knowledge, this is the first account of home range size and habitat selection of Eastern

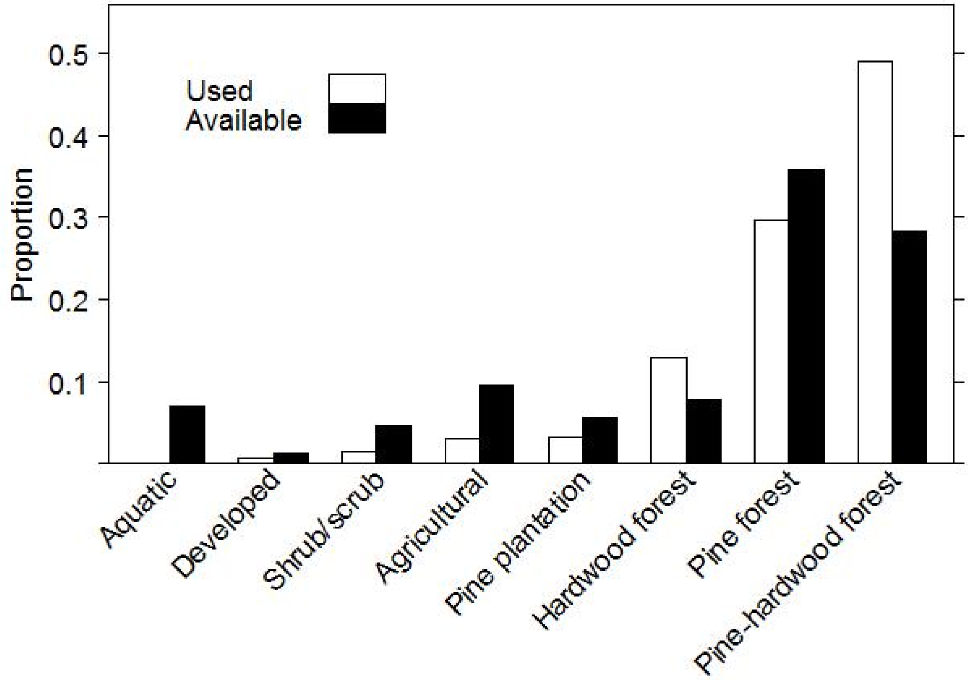

Figure 2. Average proportional habitat use (95% MCP) by *Terrapene carolina carolina* relative to availability (study area) at Ichauway reserve, Baker County, Georgia, USA. Habitat compositions of KDEs were similar to MCPs and are not shown.

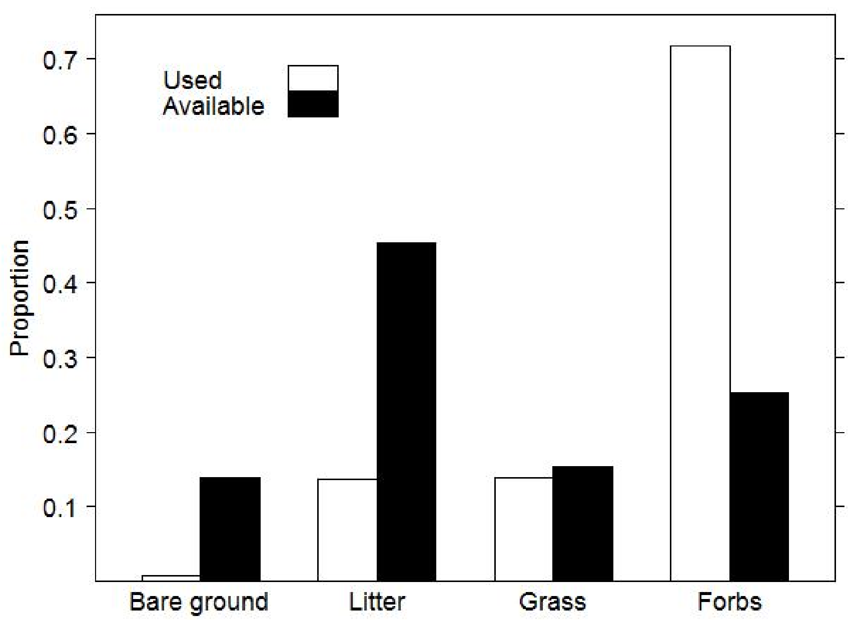

Figure 3. Average proportional groundcover use by *Terrapene carolina carolina* relative to availability at Ichauway reserve, Baker County, Georgia, USA.

Box Turtles in a Longleaf Pine landscape matrix. Longleaf Pine-dominated forests at Ichauway and throughout the Southeastern Coastal Plain are managed with frequent prescribed fire. Studies in other regions have reported injuries and mortality of box turtles from fire (Babbitt and Babbitt 1951; Platt et al. 2010). Our findings indicate, however, that despite risk to individuals from occasional fires, fire-maintained forests may offer important benefits to Eastern Box Turtle populations in the southeastern United States.

Home range sizes of Eastern Box Turtles on the Ichauway reserve were highly variable as has been reported for the species in other habitats (Dodd 2001). Previously reported average MCPs in the southeastern US are 1.88 ha (Tennessee: Donaldson and Echternacht 2005), 2.68 ha (North Carolina: Kapfer et al. 2013), and 6.45 ha (North Carolina: Hester et al. 2008). Average home range size in our study was comparatively high (10.33 ha) owing to one male and one female with home ranges > 40 ha. For the male (#1135; Appendix 1), tracking coincided with two long movements across and returning across a two-lane highway in April (1,913 m over 8 d in one direction and 1,757 m over 2 d on the return). The female (#1142) moved at least 553 m over 3 d in July (184.4 m/d). Box turtles in Georgia mate from April to June and nest in late spring or summer (Cash and Gibbons 2008); thus, it is possible that these extended movements over a short period of time were related to mate searching and nesting (Stickel 1950; Iglay et al. 2007). Excluding these two individuals, our estimate of MCP home range size was 5.87 ha, which is closer to that reported in surveys elsewhere in the southeastern US (Donaldson and Echternacht 2005, Hester et al. 2008, Kapfer et al. 2013). Additional long-term research is needed to more fully predict the spatial requirements of the species at the regional level and in response to land use change from urban and agricultural development. However, our home range findings highlight the importance in conservation planning of protecting wildlife corridors and contiguous tracts of suitable habitat to ensure that large home ranges can be accommodated when they are essential for survival and reproduction.

Our compositional analysis revealed habitat selection at the landscape scale but not within home ranges, underscoring the value of a two-stage approach to analyses of habitat use (Aebischer et al. 2003). Specifically, the turtles that we tracked favored pine-hardwood forest and hardwood forest in our study area. On Ichauway, pine-hardwood forest is found on a wide soil moisture gradient from upland sand ridges to wetland edges but is generally characterized as a mesic habitat with a significant component of Longleaf Pine (Kirkman et al. 2001). Hardwood forests on Ichauway generally occur in proximity to streams (Fig. 1) on more mesic soils (Jacqmain et al. 1999; Goebel et al. 2001). The association between Eastern Box Turtles and mesic forests is well supported by previous work (reviewed by Dodd 2001) and is linked to the species' thermal and hydric requirements (Reagan 1974; Rossell et al. 2006). Mesic forests typically have dense tree canopies. These canopies can moderate temperatures and retain understory humidity but still permit intermittent sunlight penetration and basking opportunities (Dodd 2001). On Ichauway and throughout the Southeastern Coastal Plain, frequent fire leads to similarities in floral attributes between pine-hardwood forests and Longleaf Pine savanna. Similarities include diverse native groundcover (Lemon 1949; Walker and Peet 1984; Kirkman et al. 2001) and high faunal diversity (Guyer and Bailey 1993), with the oak component adding canopy cover, vertical structure, seedlings, and coarse woody debris. Although the ecological role of oaks in Longleaf Pine ecosystems is heavily debated, Hiers et al. (2014) contend that increased canopy closure by pyrophytic oaks (i.e., oak species such as *Q. falcata* that are associated with fire-prone uplands) typically does not significantly affect understory diversity at the stand scale. They also suggest that presence of pyrophytic oaks may facilitate increased arthropod diversity and biomass, thus potentially increasing habitat quality (e.g., forage) for some species, including the Eastern Box Turtle. At a fine scale, turtles in our study preferred patches of forbs and avoided bare ground, litter, and grass substrates. Additional research is needed to determine whether this groundcover provides more suitable foraging and thermoregulatory environments than other available groundcover types. If this is the case, it might explain our observation that turtles avoided pine plantations and agricultural areas, which lack groundcover vegetation.

Our results contribute new information to the body of literature on the habitat requirements of this species in the southeastern United States and shed light on the value of ecological awareness in regional forest management. Specifically, although removal of hardwoods is typically a major element of Longleaf Pine forest management, our study supports the view that a modest upland-associated oak component can increase the ecological value of Longleaf Pine forests when combined with prescribed fire (Hiers et al. 2014). Knowledge of home range size and habitat selection of Eastern Box Turtles is critical for establishing habitat conservation and restoration priorities, especially considering continuing loss of forested habitats to urban and agricultural development throughout the range of this species and growing concern for infectious diseases (Feldman et al. 2006; Johnson et al. 2008). Given the dominance on the southeastern landscape of large-scale agriculture and urban/ suburban development, we encourage future research on the habitat preferences of Eastern Box Turtles in non-forested sites.

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Literature Cited

Aebischer, N.J., P.A. Robertson, and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radiotracking data. Ecology 74:1313–1325.

Arvisais, M., J.C. Borgeois, E. Levesque, C. Daigle, D. Masse, and J. Jutras. 2002. Home range and movements of a Wood Turtle (*Clemmys insculpta*) population at the northern limit of its range. Canadian Journal of Zoology 80:402–408.

Babbitt, L.H., and C.H. Babbitt. 1951. A herpetological study of burned-over areas in Dade County, Florida. Copeia 1951:79.

Boring, L.R. 2001. The Joseph W. Jones Ecological Research Center: co-directed applied and basic research in the private sector. Pp. 233–258 In Holistic Science: The Evolution of the Georgia Institute of Ecology (1940–2000). Barrett, G.W., and T.L. Barrett (Eds.). Taylor & Francis, New York, New York, USA.

Burt, W.H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 2:346–352.

Cagle, F.R. 1939. A system for marking turtles for future identification. Copeia 1939:170–172.

Carr, A. 1952. Handbook of Turtles. Comstock Publishing Associates, Ithaca, New York, USA.

Chamberlain, M.J., B.D. Leopold, and L.M. Conner. 2003. Space use, movements, and habitat selection of adult Bobcats (*Lynx rufus*) in central Mississippi. American Midland Naturalist 149:395–405.

Cash, W.B., and J.W. Gibbons. 2008. Eastern box turtle. Pp.407–499 In Amphibians and Reptiles of Georgia. Jensen, J.B., C.D. Camp, W. Gibbons, and M.J. Elliott (Eds). University of Georgia Press, Athens, USA.

Conner, L.M., and I.A. Godbois. 2003. Habitat associated with daytime refugia of Fox Squirrels in a Longleaf Pine forest. American Midland Naturalist 150:123–129.

Dodd, C.K. 2001. North American Box Turtles: a Natural History. The University of Oklahoma Press, Norman, Oklahoma, USA.

Dodd, C.K., R. Franz, and L.L. Smith. 1994. Activity patterns and habitat use of box turtles (*Terrapene carolina bauri*) on a Florida island, with recommendations for management. Chelonian Conservation and Biology 1:97–106.

Donaldson, B.M., and A.C. Echternecht. 2005. Aquatic habitat use relative to home range and seasonal movement of Eastern Box Turtles (*Terrapene carolina carolina*: Emydidae) in Eastern Tennessee. Journal of Herpetology 39:278–284.

Drew, M.B., L.K. Kirkman, and A.K. Gholson, Jr. 1998. The vascular flora of Ichauway, Baker County, Georgia: a remnant Longleaf Pine/Wiregrass ecosystem. Castanea 63:1–24.

Ernst, C.H., and J.E. Lovich. 2009. Turtles of the United States and Canada. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Feldman, S.H., J. Wimsatt, R.E. Marchang, A.J. Johnson, W. Brown, J.C. Mitchell, and J.M. Sleeman. 2006. A novel *Mycoplasma* detected in association with upper respiratory disease syndrome in free-ranging Eastern Box Turtles (*Terrapene carolina carolina*) in Virginia. Journal of Wildlife Diseases 42:279–289.

Frost, C.C. 1993. Four centuries of changing landscape patterns in the Longleaf Pine ecosystem. Proceedings of the Tall Timbers Fire Ecology Conference 18:17–43.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poppy, et al. 2000. The global decline of reptiles, déjà vu amphibians. BioScience 50:653–666.

Goebel, C.P., B.J. Palik, L.K. Kirkman, M.B. Drew, L. West, and D.C. Pederson. 2001. Forest ecosystems of a Lower Gulf Coastal Plain landscape: multifactor classification and analysis. Journal of the Torrey Botanical Society 128:47–75.

Guyer, C., and M.A. Bailey. 1993. Amphibians and reptiles of longleaf pine communities. Proceedings of the Tall Timbers Fire Ecology Conference 18:139–159.

Hall, R. J., P.F.P. Henry, and C.M. Bunck. 1999. Fifty-year trends in a box turtle population in Maryland. Biological Conservation 88:165–172.

Hester, J.M., S.J. Price, and M.E. Dorcas. 2008. Effects of relocation on movements and home ranges of Eastern Box Turtles. Journal of Wildlife Management 72:772–777.

Hiers, J.K., J.R. Walters, R.J. Mitchell, J.M. Varner, and L.M. Conner. 2014. Ecological value of retaining pyrophytic oaks in Longleaf Pine ecosystems. Journal of Wildlife Management 78:383–393.

Iglay, R.B., J.L. Bowman, and N.H. Nazdrowicz. 2007. Eastern Box Turtle (*Terrapene carolina carolina*) movements in a fragmented landscape. Journal of Herpetology 41:102–106.

Jacqmain, E.I., R.H. Jones, and R.J. Mitchell. 1999. Influences of frequent cool season burning across a soil moisture gradient on oak community structure in longleaf pine ecosystems The American Midland Naturalist 141:85–100.

Jennings, A.H. 2003. Daily and seasonal activity patterns and movements of juvenile box turtles (*Terrapene carolina bauri*) on Egmont Key, Florida. Chelonian Conservation and Biology 4:578–587.

Johnson, A.J., A.P. Pessier, J.F. Wellehan, A. Childress, T.M. Norton, N.L. Stedman, D.C. Bloom, W. Belzer, V.R. Titus, R. Wagner, et al. 2008. Ranavirus infection of free-ranging and captive box turtles and tortoises in the United States. Journal of Wildlife Diseases 44:851–863.

Johnson, D.H. 1980. Comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Kapfer, J.M., D.J. Muñoz, J.D. Groves, and R.W. Kirk. 2013. Home range and habitat preferences of Eastern Box Turtles (*Terrapene carolina* Linnaeus, 1758) in the Piedmont Ecological Province of North Carolina (USA). Herpetology Notes 6:251–260.

Kaufmann, J.H. 1995. Home ranges and movements of Wood Turtles, *Clemmys insculpta*, in central Pennsylvania. Copeia 1995:22–27.

Kirkman, L.K., M.B. Drew, L.T. West, and E.R. Blood. 1998. Ecotone characterization between upland Longleaf Pine / Wiregrass stands and seasonally-ponded isolated wetlands. Wetlands 18:346–364.

Kirkman, L.K., R.J. Mitchell, R.C. Helton, and M.B. Drew. 2001. Productivity and species richness across an environmental gradient in a fire-dependent ecosystem. American Journal of Botany 88:2119–2128.

Lemon, P.C. 1949. Successional responses of herbs in the Longleaf-Slash Pine forest after fire. Ecology 30:135–145.

Miller, G.J. 2008. Home range size, habitat associations and refuge use of the Florida Pine snake, *Pituophis melanoleucus mugitus*, in southwest Georgia, USA. M.S. Thesis, University of Florida, Gainesville. 72 pp.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. The American Midland Naturalist 37:223–249.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541–545.

Nichols J.T. 1939. Data on size, growth and age in the box turtle, *Terrapene carolina*. Copeia 1939:14–20.

Nieuwolt, P.M. 1996. Movement, activity, and microhabitat selection in the Western Box Turtle, *Terrapene ornata luteola*, in New Mexico. Herpetologica 52:487–495.

Platt, S.G., H. Liu, and C.K. Borg. 2010. Fire ecology of the Florida Box Turtle (*Terrapene carolina bauri* Taylor) in pine rockland forests of the lower Florida Keys. Natural Areas Journal 30:254–260.

Reagan, D.P. 1974. Habitat selection in the Three-toed Box Turtle, *Terrapene carolina triunguis*. Copeia 1974:512–527.

Rodgers, A.R., A.P. Carr, H.L. Beyer, L. Smith, and J.G. Kie. 2007. HRT: Home Range Tools for ArcGIS. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario, Canada.

Rossell, Jr., C.R., I.M. Rossell, and S. Patch. 2006. Microhabitat selection by Eastern Box Turtles (*Terrapene c. carolina*) in a North Carolina mountain wetland. Journal of Herpetology 40:280–284.

Row, J.R., and G. Blouin-Demers. 2006. Kernels are not accurate estimators of home range size for herpetofauna. Copeia 2006:797–802.

Schwartz, E.R., C.W. Schwartz, and A.R. Kiester. 1984. The Three-toed Box Turtle in Central Missouri, Part II: A Nineteen Year Study of Home Range, Movements and Population. Missouri Department of Conservation Terrestrial Series 12.

Stickel, L.F. 1950. Populations and home range relationships of the box turtle, *Terrapene c. carolina* (Linnaeus). Ecological Monographs 20:351–378.

Stickel L.F. 1978. Changes in a box turtle population during three decades. Copeia 1978:221–225.

Stickel, L.F. 1989. Home range behavior among box turtles (*Terrapene c. carolina*) of a bottomland forest in Maryland. Journal of Herpetology 23:40–44.

Walker, J., and R.K. Peet. 1984. Composition and species diversity of pine-wiregrass savannas of the Green Swamp, North Carolina. Vegetatio 55:163–179.

Williams, Jr., E.C., and W.S. Parker. 1987. A long-term study of a box turtle (*Terrapene carolina*) population at Allee Memorial Woods, Indiana, with emphasis on survivorship. Herpetologica 43:328–335.

Worton, B.J. 1989. Kernel methods for estimating utilization distribution in home-range studies. Ecology 70:164–168.

Table A1. Body size at capture (CL = carapace length), number of times a turtle was radio-tracked, number of unique tracking locations, length of tracking period, and home range size (in ha) for 19 radio-tracked *Terrapene carolina carolina* using minimum convex polygons (MCP) and kernel density estimates (KDE), Baker County, Georgia, USA, 2003–2004. F = female; M = male; U = undetermined sex.

Turtle ID (gender)	CL (mm)	Mass (g)	Telemetry locations	No. Unique Locations	Days Tracked	95% MCP	95% KDE	50% KDE (core area)
1132 (F)	122	368	78	41	397	0.87	0.87	0.22
1133 (F)	144	570	71	37	365	3.34	3.37	0.65
1139 (F)	123	360	77	41	330	7.30	7.13	1.78
1142 (F)	140	610	69	35	350	42.02	41.62	7.41
1147 (F)	140	560	60	22	340	3.01	3.14	0.71
1151 (F)	122	390	35	27	174	0.33	0.36	0.09
3000 (F)	130	491	76	26	322	1.43	1.51	0.37
1124 (M)	127	329	90	50	401	2.12	2.00	0.52
1131 (M)	119	303	85	45	391	5.38	5.36	1.24
1135 (M)	127	385	46	18	240	54.37	53.99	10.44
1136 (M)	132	359	71	32	371	3.52	3.69	0.80
1138 (M)	132	415	63	29	336	20.48	20.75	3.81
1143 (M)	132	450	68	33	350	13.26	13.44	3.13
1144 (M)	132	428	74	35	335	1.47	1.49	0.25
1146 (M)	109	296	70	46	339	3.11	3.05	0.49
1150 (M)	127	390	35	26	174	1.54	1.56	0.28
1125 (U)	124	375	65	33	257	11.38	11.56	2.37
1137 (U)	115	330	73	38	371	9.04	8.85	1.78
1141 (U)	107	317	77	32	343	12.25	12.04	3.11
Means (SE)								
Females	132	478				8.33	8.28	1.60
	(4)	(40)				(5.68)	(5.62)	(0.99)
Males	126	373				11.70	11.70 (5.72)	2.33
	(3)	(18)				(5.75)	(5.72)	(1.10)
Overall	127	407		34	326	10.33	10.30	2.08
	(2)	(21)		(2)	(15)	(3.33)	(3.30)	(0.62)

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